A Tale of Two Index Futures: The Intraday Price Discovery and Volatility Transmission Processes between the China Financial Futures Exchange and the Singapore Exchange

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***ABSTRACT*:** This is the first study to examine the intraday price discovery and volatility transmission processes between the Singapore Exchange and the China Financial Futures Exchange. Using one- and five-minute high-frequency data from May to November 2011, we find that China's CSI 300 index futures dominate Singapore's A50 index futures in both intraday price discovery and intraday volatility transmission processes. However, A50 futures contracts also make a substantial contribution (26%-37%) in the price discovery process. These results have important implications for both traders and policymakers.

KEY WORDS: price discovery, volatility transmission, futures market, CSI 300, A50, information share.

On September 5, 2006, the Singapore Exchange issued SGX FTSE Xinhua China A50 index futures, which remain the only offshore futures on China's broad A-share markets. Three days later, the China Financial Futures Exchange (CFFEX) was established in Shanghai, which began the four-year-long preparation for China's own index futures. On September 18, 2006, the Shanghai Stock Exchange filed a lawsuit against FTSE XINHUA Co., claiming that its permission for the Singapore Exchange's use of data provided by the Shanghai Stock Exchange to compile the A50 index was illegal. In November 2006, the Shanghai court ruled in favor of the Shanghai Stock Exchange and fined FTSE XINHUA Co. USD 20,000. The latter appealed to the higher court but was rejected, ending the year-long legal battle. Witnessing the ever-decreasing trading volume of A50 futures, the Singapore Exchange reduced the contract size in November 2007 to increase the trading volume but saw it slide back to almost zero volume by the end of 2008. On April 16, 2010, the CFFEX finally introduced its long-awaited CSI 300 index futures after a four-year experiment based on mock trading between large qualified domestic institutions. In response, on August 23, 2010, the Singapore Exchange started making a series of substantial revisions to A50 futures contract specifications to increase its competitiveness. The revisions made so far include extended trading hours, reduced entry barriers, smaller contract sizes, and lower margin requirements. The trading volume since then has increased dramatically.

This fierce competition between exchanges in China and Singapore for a dominant role in China's A-share index futures contracts has received considerable attention from global investors, media, and policymakers for several reasons. First, the Singapore Exchange introduced SGX Nikkei 225 Index Futures and SGX MSCI Taiwan Index Futures well before these two markets introduced their own futures contracts. Previous studies have shown that these offshore contracts have had considerable influence on the domestic markets (e.g., Roope and Zurbruegg 2002; Covrig, Ding, and Low 2004; Chung and Hseu 2008; Hsieh and Ma 2009). Second, China is the latest market to introduce its own financial futures. Thus, its success has critical implications for the introduction of more advanced financial derivative products such as index and stock options. Many foreign institutions are interested in such potential investment opportunities in China's expanding financial markets. Third, in the short run, CSI 300 futures are likely to remain the only domestic financial product that investors can use to hedge against or speculate on China's broad A-share markets. The competition between CSI 300 futures and A50 futures may directly influence the investment decision and profitability of those investors who heavily rely on the direction of information flow. This issue has become particularly relevant because, since the last contract revisions by the Singapore Exchange, there have been dramatic increases in A50 futures trading volume and open interest.

Thus, the price discovery and volatility transmission processes between the two index futures represent interesting and meaningful research questions.[1] However, although some studies have examined the price

[1] The issues related to price discovery and volatility transmission have been steady research topics. For example, Crain and Lee (1995) and Chatrath and Song (1998) examine the volatility spillover between FX futures markets and FX spot markets. Chen and Gau (2010) use the information share approach to examine the

discovery process between SGX Nikkei 225 (SGX MSCI Taiwan) index futures and Nikkei 225 index futures (TAIFEX futures), few have addressed this process and none has investigated the volatility transmission between A50 and CSI 300 index futures. In this regard, we investigate the role of the Singapore Exchange in the competition for China's index futures markets. Specifically, the paper examines the pairwise price discovery and volatility transmission processes between the CSI 300 index, newly introduced CFFEX CSI 300 index futures, SGX FTSE Xinhua China A50 index, and A50 index futures markets.

We employ conventional methods in the price discovery literature, including the Granger causality test, the Hasbrouck information share, and the Gonzalo and Granger information share. Consistent with the findings of previous studies for other markets, our results indicate that each futures market dominates the corresponding spot market. The CSI (A50) futures market dominates the CSI (A50) spot market, representing a 76% (76%) Gonzalo and Granger information share at the one-minute frequency and a 61% (84%) information share at the five-minute frequency. Despite its relatively thin trading volume, between the two futures markets, A50 futures contributes 26% at the one-minute frequency and 37% at the five-minute frequency to price discovery process in terms of the Hasbrouck information share, implying that after a year and a half, the CSI 300 futures market becomes mature and assumes its function as a leading marketplace for the price discovery process. On the volatility transmission side, the CSI 300 futures market also dominates its Singapore counterpart, further confirming the leading role of the Chinese futures market in the intraday trading of the futures based on the Chinese A-share market. But again the role of the A50 futures market in the volatility transmission isn't negligible.

Few studies have focused on the CSI 300 index futures market because it is relatively new. Yang, Yang, and Zhou (2011) examine the price discovery process between the CSI 300 index and CSI 300 index futures

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price discovery between futures and spot rates of the EUR-USD and JPY-USD markets. Min and Najand (1999) and Nam et al. (2006) investigate the price discovery issues between spot and index derivatives markets in Korea. They find a clear lead-lag relationship among these markets. Recently, the study of Ryu (2011), which extends Madhavan et al. (1997) and Ahn et al. (2008, 2010), deals with the market microstructure issues using the price discovery and market linkage relationship between the index futures and options markets.

markets by using high-frequency data from April 16, 2010, to July 30, 2010, and find that during this early stage, the CSI 300 futures market lags behind the spot market in information flow and that there is some bidirectional intraday volatility transmission between the two markets. The present study uses an extended period of data and finds a dominant role of the CSI 300 futures market in both price discovery and volatility transmission processes, indicating that the CSI 300 futures market has become more mature compared with when it was introduced.

CSI 300 Index Futures and A50 Index Futures

CSI 300 index futures are traded on the CFFEX, and its underlying asset is the CSI 300 index, which is composed with the 300 largest A-shares listed on the Shanghai Stock Exchange (179 stocks) and the Shenzhen Stock Exchange (121 stocks) by China Securities Index Co., Ltd. The trading volume of CSI 300 index futures increased sharply from 5,487,908 to 7,536,922 contracts in the first three months of trading, and the total turnover was over RMB 6,000 billion as of 2010. Figure 1 shows the daily trading volume from the first day of trading to November 21, 2011. There was a small decrease in average trading volume after August 23, 2010, when the Singapore Exchange revised its A50 futures contract specifications, but it increased since the latter half of 2011.

The CSI 300 index futures market is completely order-driven. There is no designated market maker, and trading is conducted using a central computer system that matches buy and sell orders. Regular trading hours are from 09:15 to 11:30 and from 13:00 to 15:15, which means that it opens 15 minutes earlier and closes 15 minutes later than the spot market. However, for the purpose of price convergence, on each settlement day, the futures market closes at the same time as the spot market (15:00). Five types of futures contracts are traded simultaneously. Their expiration dates fall over the next three consecutive months and the two nearest quarter-end months (i.e., March, June, September, and December). The third Friday of each month is the settlement day, and the settlement price is calculated as the arithmetic average of the spot CSI 300 index during the last two trading hours of that day. The contract multiplier for each point is set as RMB 300. Regulators set RMB 500,000 as the minimum amount for opening a futures trading account, and the initial margin for each futures contract is 12% of its total value, that is, 12%×300×current futures price. The strict entry condition and the high-margin requirement limit noise traders. Similar to the spot market, the futures market has a daily price limit of ±10% with respect to the settlement price of the last trading day. In addition, there is a "circuit breaker" set at ±6%. Specifically, when changes in the daily futures price exceed ±6% and last for more than a minute, the circuit breaker is activated, and in the following 10 minutes, the bid/ask quotes are restricted to a range between -6% and 6%. Any quotes beyond this range are automatically denied. After 10 minutes, the price limit is expanded to ±10%, and normal trading activities resume. The circuit breaker is designed as a cooling-off system for stabilizing the market in extremely volatile conditions.

SGX FTSE Xinhua A50 index futures are written on the SGX FTSE Xinhua A50 index, which is composed of the largest 50 A-share firms by full market capitalization. They are stocks listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange and account for approximately 45% of the total market capitalization of the A-share market. The index is highly correlated with the CSI 300 index and A-share ETFs, and major investors (including qualified foreign institutional investors (QFIIs) and hedge funds) employ A50 futures to hedge against, speculate on, or invest in China's A-share markets. The contract months for A50 futures are the two nearest serial months and March, June, September, and December on a one-year cycle. The last trading day is the second-last business day of the contract month. In August 2010, the contract size was reduced to USD 1 from USD 10 multiples of the futures price. Both T and T+1 sessions offered extended trading hours: The lunch break was cancelled for a continuous T session from 9 a.m. to 3:25 p.m. (before it was from 9:15 a.m. to 11:35 a.m., and from 1:00 p.m. to 3:05 p.m.), and the T+1 session traded from 4:10 p.m. to 2:55 a.m. the next day, which was from 3:40 p.m. to 10:55 p.m. In addition, the initial margin was reduced from USD 1,500 to USD 688 and further to USD 563, and the maintenance margin was cut down to USD 450 from USD 550. As shown in Figure 1, one striking phenomenon is that the trading volume, which was extremely low before the contract revisions in August 2010, increased sharply since then. This study is motivated by this observation.

Data Description

We consider a sample period from May 9, 2011, to November 21, 2011, when the CSI 300 index futures market has been in operation for more than one and a half years and it has been nine months since the Singapore Exchange revised its A50 futures contract specifications. Over the sample period, the CSI 300 spot index decreases from 3,164 to around 2,500.

We obtain one-minute data on the CSI 300 index, CSI 300 index futures, the A50 index, and A50 index futures from Bloomberg via Nanhua Futures Co., a leading futures brokerage and research institute in China. We compute the mid-quote price in the bid-ask spread to construct the price series. Because the four markets have different trading sessions, we consider the common trading hours from 9:35 a.m. to 11:25 a.m. and from 1:05 p.m. to 2:55 p.m. for each trading day. We exclude the first and last five minutes in each trading session to avoid noise trades during opening and closing hours.[2] To construct a continuous series of futures contracts, we select only the most active futures contracts, that is, the contracts with the nearest maturity dates but without those with less than one week to maturity to avoid expiration day effects. A50 futures are traded in USD, whereas CSI 300 futures, in RMB. Thus, A50 futures prices should ideally be adjusted by the RMB/USD exchange rate. However, there is little change in this exchange rate over the sample period because of China's policy of managed floating rates: The average daily change in the exchange rate is -0.01% (S.D.=0.11%). For this reason, we analyze only unadjusted A50 futures prices.[3] In addition, we normalize the four series by

[2] In an unreported study we include the last five minutes in the morning session and the first five minutes in the afternoon session but find no qualitative differences in results.

[3] Ideally, we should have used the one-minute exchange rate for the adjustment, but we could obtain no intraday data. However, we expect no substantial impact on the results because we conduct the analysis based on the log return of the price series, not on the price itself. That is, taking the log of the price removes most the variations in the exchange rate, which should not be large for a managed floating rate. We conduct an additional analysis and verify that the use of the daily FX-adjusted price series has no influence on the results.

setting the first-day price/the index value in each series to be 1,000. As a result, we obtain a total of 29,541 data points for each series.

To examine how the price discovery and volatility transmission processes evolved over time intervals, we construct a five-minute price series for each market. Following Roope and Zurbruegg (2002), we take the average of the two closest prices on both sides of the five-minute breaker to remove the potential downward bias from the use of the price closest to the five-minute breaker. We conduct all the tests for both one-minute and five-minute series.

We take the log of one-minute (five-minute) returns for all series and compute their correlations (Table 1).[4] As shown in Panel A, for the one-minute interval, CSI spot and futures returns show little synchronization with a low correlation of 0.35. This may be because in practice it typically takes a hedger more than one minute to execute a buy/sell order for all 300 stocks in the index. In comparison, A50 spot and futures returns show some co-movement (correlation=0.67), possibly because only about 15 seconds are needed to execute an order for A50 component stocks. This difference reflects the advantage of the Singapore futures market over the Chinese futures market in terms of the adjustment speed and hedging efficiency relative to each spot market. The two futures markets have the highest correlation (0.73), and the correlation between the two spot markets is 0.63, indicating some information flow between Singapore and China. Panel B shows the correlations for the five-minute return series. For longer time intervals, more information is incorporated into prices, and thus, there are substantial increases in all the correlations. For example, the correlation between CSI spot and futures returns increases sharply to 0.75, and that between the two spot (futures) markets increase to 0.91 (0.89).

Table 2 shows the descriptive statistics for each series. The results of the Augmented Dickey–Fuller (ADF) test indicate that all price series fail to reject the null hypothesis of a unit root but that the return series justify the assumption of stationarity. The two futures series are less skewed and heavy-tailed than their spot series at the one-minute frequency but have approximately the same high moments at the five-minute frequency. In

[4] We exclude the first log return to avoid the bias associated with overnight returns.

addition, for all series, five-minute returns have much less excess kurtosis than one-minute returns because of the smoothing effect.

Methods and Empirical Results

Price Discovery Process

We employ three well-known techniques to examine the price discovery processes between the four markets. To apply these methods, we first check whether the four price series share a common long-run stochastic trend. Intuitively, the four markets should share a common driving force, that is, the Chinese A-share stock market. We conduct the standard Johansen (1991) trace test to determine the number of common long-run trends (Table 3).[5] Panels A and B of Table 3 show three cointegration vectors for the one-minute series at the 5% level of significance and for the five-minute series at the 10% level, indicating a single long-run equilibrium point for the four series. Based on these results, we investigate the price discovery processes between the two futures markets, between the two indices, and between each futures market and its underlying index.

For the first method, we conduct a pairwise block exogeneity test with lagged returns for the four series. Equation 1 shows an error correction model (ECM) for markets i and j:

$$\Delta p_{i,t}=\alpha(p_{i,t-1}-p_{j,t-1})+\sum\nolimits^{N}_{k=1}(\beta_{i,k}\Delta p_{i,t-k}+\beta_{j,k}\Delta p_{j,t-k})+\gamma D_t+\varepsilon_t \tag{1}$$

where p denotes the log price vector; α represents the adjustment speed for markets i and j; β_k is the autoregressive coefficient for lag k; N is the number of lags (N=15); and D_t is a trend term.[6] Equation 1 separates short-term effects from long-term ones, allowing for the determination of whether market j Granger-causes market i (via a joint test that all coefficients $\beta_{j,k}$ are significantly different from zero) and whether market

[5] Because of the deterministic decreasing trend during the sample period (Figure 2), we conduct the Johansen trace test by assuming a linear trend component. The results of a unit root test for the four detrended series verify that all the detrended series are I (1) processes. We select the optimal 15 lags for the Johansen trace test by using the Akaike information criterion (AIC) and employ the same lag structure for the rest of empirical analyses.

[6] All the tests assume the existence of a linear trend component.

j is adjusting toward market i through a test of the statistical significance of α.

Panel A of Table 4 indicates that there are bidirectional lead-lag relationships between Singapore and China at the one-minute frequency and that the A50 futures market doesn't have a significant effect on the movement of the CSI 300 futures market at the 10% level. For each spot-futures pair, the futures market is more likely to influence its spot index than the other way round, as indicated by the F-statistic. For example, the F-value for the test that CSI 300 (A50) futures does not Granger-cause CSI 300 (A50) spot index is 969.59 (85.46), whereas that for the test that CSI 300 (A50) spot index does not Granger-cause CSI 300 (A50) futures is 2.42 (44.27). A50 spot is much more likely to Granger-cause CSI 300 spot price than the other way round, suggesting that in the spot market, A50 investors react to new market information faster than CSI 300 investors possibly because the A50 index includes the largest 50 A-share firms. The results for the adjustment speed reveal three important points. First, the speed coefficient for the futures market is lower than that for the spot market for both Singapore and China, indicating that the spot market is more likely to adjust toward the futures market than the other way round. Second, the speed coefficient for the A50 futures market is much higher than that for the CSI 300 futures market, indicating that the A50 futures market tends to adjust toward the CSI 300 futures market. Third, the coefficients for both the A50 and CSI 300 spot markets are significant at the 10% level, although the coefficient for the A50 is higher, indicating the mutual adjustment of these two markets. This result is not surprising because these two markets, roughly speaking, represent the same Chinese market. The results for the coarser five-minute level (Panel B) indicate similar observations. However, the effects of the two spot markets on their respective futures markets are weaker and insignificant, indicating that the spot markets lead the futures markets only temporarily.

For the second method, we employ Hasbrouck's (1995) information share, which measures the contribution of a particular market to the total variation in common trend innovations that drive two markets. Table 5 shows the mean and upper/lower bounds of information shares for each pair of the four markets. The results indicate that CSI futures contribute more to the price discovery process than A50 futures. However, A50 futures also make substantial contributions (26%-37%) to the total variation in price common trend innovations. This finding, although being reasonable due to the relatively small size of the trading volume for A50 futures, is revealing because previously investors and Exchange policy makers expect a much smaller role played by the A50 futures in the price discovery process between the two markets. Between the two spot markets the A50 spot market contribute approximately 40% to the price discovery process, consistent with the result of the Granger causality test in Table 4, which indicates the mutual influence of the spot markets. In addition, the results confirm that both CSI futures and A50 futures dominate their respective spot markets. Yang, Yang, and Zhou (2011) report that CSI futures don't play a leading role in the price discovery process for the first three and a half months, possibly because of high entry barriers. The present study's results indicate that in about one and a half years after its introduction, the CSI futures market establishes its price discovery function and dominates the spot market in information flow. At the five-minute frequency, results are qualitatively similar, although most dominance diminishes except for the CSI spot market versus the A50 spot market.

For the final method, we employ the Gonzalo-Granger (1995) information share, another measure that focuses on the contribution of each market in influencing an implicit efficient price that is common to two markets (Table 6). The results indicate similar patterns for one- and five-minute series. For instance, for the one-minute series, the CSI 300 futures market clearly dominates the A50 futures market (77% vs. 23%); each futures market leads its spot market (76% vs. 24% for China and Singapore, respectively); and the CSI 300 spot market leads the A50 spot market (77% vs. 23%).

In summary, the Chinese market functions well in terms of its dominant contributions to the price discovery process between the markets. On the other hand, the Singapore Exchange does account for some portion of price discovery and warrants attention from Chinese Exchange policy makers. There are at least three possible reasons why the CSI 300 futures market dominates the A50 market. First, the CSI futures market and its influence grow rapidly, and thus, investors tend to enter this market when they have new information. Second, the authors' conversation with futures traders suggests that many institutional investors employ algorithmic trading for CSI 300 futures because of their large trading volume but that this is not the case for A50 futures. Third, the lead-lag relation between the two futures markets could be due to the fact that the CSI 300 spot leads the A50 spot as we find. Due to hedging purposes, domestic and foreign qualified institutional investors prefer the futures market with more liquid underlying, as a result of which the CSI futures market absorbs more timely trading information.

Although the A50 futures market's trading volume is approximately one tenth that of the CSI 300 futures market and the A50 futures market doesn't impact China's A-share market as much as initially hoped, the Singapore Exchange does have several advantages in positioning the A50 index futures market as a major destination for foreign institutional investors who wish to hedge against or speculate on China's stock markets. First, the A50 index futures market has much lower entry barriers for investors. Its contract size is only one thirteenth that of CSI futures and its initial margin is even lower. Second, the A50 futures market opens 15 minutes earlier and closes 10 minutes later than the CSI futures market. In addition, there is no lunch break in the A50 futures market. Third, the A50 futures market has an additional T+1 session that last until 2:55 a.m. the next day. When the market has unexpected news during extended T and T+1 sessions, the only place where investors can trade is the A50 futures market. Barclay and Hendershott (2003) show that low after-hour trading volume can generate significant price discovery. Fourth, the A50 futures contract is settled in USD, which is particularly convenient for Western investors. Moreover, as the only offshore index futures on the Chinese A-share market, the A50 futures market is presumably a popular destination for sophisticated foreign institutional investors. Bohl, Salm, and Schuppli (2011) show that the price discovery function of the futures market increases with the proportion of institutional investors relative to individual investors. Cai, Ho, Korajczyk, and Zhang (2012) further demonstrate that market openness, foreign accessibility and legal environment play important roles in the price discovery. Since the A50 market is much easier for access than the CSI futures market due to trade barriers set by the CFFEX, ceteris paribus the A50 market should be influential in terms of price discovery. In addition, the legal environment and law enforcement in Singapore is arguably better than that in China, also implying a significant role in price discovery.

Volatility Transmission Analysis

In this section, we further investigate the volatility transmission process among the four markets using an ECM-GARCH(1,1) model with BEKK specification as defined in Engle and Kroner (1995). Information transmission via volatility linkage across different markets is well documented in the literature. A recent example is Yang, Yang, and Zhou (2011) who examine the transmission between the CSI 300 index and CSI 300 index futures, and find a two-way volatility transmission.

Let the conditional 2×2 covariance matrix of the log returns Δp_t of the two assets be denoted as H, a bivariate ECM-GARCH(1,1)-BEKK model has the following form:

$$\Delta p_t=\mu+\sum_{k=1}^{N}\beta_k\Delta p_{t-k}+\gamma D_t+\varepsilon_t, \quad where\ \varepsilon_t|\Omega_{t-1}\sim N(0, H_t) \tag{2}$$

$$H_t=CC^T+A^T\varepsilon_{t-1}\varepsilon_{t-1}^T A+B^T H_{t-1}B \tag{3}$$

where u is an intercept vector, N the number of lags, D_t a vector of trend terms, A, B, and C 2×2 parameter matrices, and C an upper triangular matrix. Specifically, expanding equation (3) yields

$$H_t=\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix}=\begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}\begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}^{\mathrm{T}}+\begin{bmatrix} a_{11} & a_{12} \\ 0 & a_{22} \end{bmatrix}^{\mathrm{T}}\varepsilon_{t-1}\varepsilon_{t-1}^{T}\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$
$$+\begin{bmatrix} b_{11} & b_{12} \\ 0 & b_{22} \end{bmatrix}^{\mathrm{T}}H_{t-1}\begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \tag{4}$$

We then use the off-diagonal parameters in matrices A and B to explain volatility transmission effect. For example, when analyzing the spillover between the CSI 300 index market and the CSI 300 futures market, a_{12}^2 (a_{21}^2) measures the transmission of the squared values of lagged returns from the CSI 300 index (futures) market to the current period's conditional volatility in the CSI 300 futures (index) market; b_{21}^2 (b_{12}^2) measures the dependence of the conditional volatility in the CSI 300 index (futures) market on that of the CSI 300 futures (index) market of the previous period.

Panel A (Panel B) in Table 7 presents the results for 1-minute (5-minute) results. Matrices A in both panels tell us that the CSI 300 futures volatility strongly depends on the squared return shocks of the lagged CSI 300 spot. The same is observed for the A50 spot and A50 futures. The lagged values of the squared return shocks of the CSI 300 futures overwhelmingly affect the current conditional volatility of the A50 futures, while the opposite is not only insignificant but also negligible at large. Similar conclusion can be made between the CSI 300 spot and the A50 spot, except that at the 5-minute frequency the effect of the CSI 300 return shocks is insignificant. Matrices B in both panels tell us further that the volatilities of these two futures markets clearly depend on each other, with the dependence of the A50 futures volatility on that of the CSI 300 futures is much larger than the other way round. The lagged conditional volatility of the CSI 300 spot has a disproportionately large impact on that of the A50 spot. At the 5-minute frequency the volatilities of the CSI 300 spot and the CSI 300 futures affect each other. The volatilities of the A50 spot and A50 futures markets depend on each other, with a larger effect from the spot to the futures market. In a sum, the CSI 300 spot and futures markets lead the A50 spot and futures markets in the volatility transmission process, reflecting the dominating role of the Chinese futures market[7].

Conclusions

This paper examines the intraday price discovery and volatility transmission processes between the CSI 300 spot, A50 spot, CSI 300 index futures, and A50 index futures markets. The results indicate that on average the CSI 300 futures outperform A50 futures in the price discovery process. Based on two well-known measures of the information share, CSI 300 futures lead A50 futures and contribute more to the price discovery process. In addition, both the Chinese spot and futures markets dominate their Singapore counterparts in the volatility transmission process, suggesting an increasingly powerful role played by the Chinese futures market after one and a half years of operation. However, given that the A50 futures market is much smaller than the CSI 300

[7] As the Chinese economy and financial market integrate more with the world markets after China joins the WTO and gradually opens its financial market, it is quite reasonable to conjecture that new information and return volatility may also pass through across financial markets in other countries such as US index futures market and the Chinese index futures market. As an example, a very recent study by Corradi et al. (2012) investigate the volatility transmission between China, Japan, UK, and US and find significant interconnection. In particular, the spillover from China to US is very pronounced after controlling for the quadratic variation in the UK.

futures market in absolute as well as relative terms, its 26%-37% information share is relatively large. These results suggest that Chinese policymakers should continue to pay close attention to the development of the A50 futures market, particularly because (as shown in Figure 1) the trading volume of A50 futures grow faster than that of CSI 300 futures since August 23, 2010. As a strategy, the Chinese futures market can reduce its contract sizes and entry barriers to attract more retail investors and foreign investors. Taiwan's TAIFEX market played a minor role compared to the MSCI Taiwan index futures until it reduces its capital gain tax rate. In this regard, future research should examine which factors (e.g., trading volume, market makers, the T+1 session, and information origin) are the most important in the price discovery and volatility transmission function of A50 futures contracts. Another potential research topic could be to investigate the lead-lag relation between order imbalances of the futures transactions in the two markets. This should provide new insight on how information flow is transmitted across markets from the perspective of behavioral finance[8]. In any case, the competition between the Singapore Exchange and the CFFEX for the dominance of financial futures is far from over, and it is still premature to declare the winner.

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Table 1. Correlation matrix for index and index futures markets

	CSI 300 Spot	CSI30 Futures	A50 Spot	A50 Futures
Panel A: One-Minute Returns				
CSI 300 Spot	1.0000			
CSI 300 Futures	0.3506	1.0000		
A50 Spot	0.6323	0.6215	1.0000	
A50 Futures	0.4158	0.7346	0.6668	1.0000
Panel B: Five-Minute Returns				
CSI 300 Spot	1.0000			
CSI 300 Futures	0.7535	1.0000		
A50 Spot	0.9170	0.8437	1.0000	
A50 Futures	0.7611	0.8913	0.8627	1.0000

Notes: This table presents the correlation matrix of the log returns of the four assets: CSI 300 spots, CSI 300 futures, A50 spots and A50 futures. Panel A is for one-minute returns and panel B is for five-minute.

Table 2. Summary statistics for index and index futures markets

	CSI 300 Spot	CSI30 Futures	A50 Spot	A50 Futures
Panel A: One-Minute Returns				
ADF (log prices)	-2.2739	-2.2362	-2.4111	-2.4070
Prob (log prices)	0.4622	0.4783	0.4040	0.4057
ADF (returns)	-42.3113	-42.6009	-42.3690	-42.3761
Prob (returns)	0.0100	0.0100	0.0100	0.0100
Mean	-0.0003	-0.0005	-0.0002	-0.0004
Std. Dev.	0.0469	0.0662	0.0528	0.0662
Skewness	1.3837	0.5323	1.3801	0.6061
Excess Kurtosis	19.3851	12.1116	18.0320	7.8223
Panel B: Five-Minute Returns				
ADF (log prices)	-2.3472	-2.3450	-2.4567	-2.4566
Prob (log prices)	0.4313	0.4322	0.3849	0.3850
ADF (returns)	-22.6207	-22.0993	-22.9433	-22.5326
Prob (returns)	0.0100	0.0100	0.0100	0.0100
Mean	-0.0018	-0.0027	-0.0018	-0.0023
Std. Dev.	0.1507	0.1521	0.1430	0.1493
Skewness	0.6666	0.6315	0.8790	0.6194
Excess Kurtosis	5.0099	6.0364	5.1680	4.3111

Notes: This table shows the statistics (mean, standard deviation, skewness and excess kurtosis) for log returns, together with the results of the Augmented Dickey–Fuller (ADF) test of a unit root for both log prices and returns. Panel A is for one-minute returns and panel B is for five-minute.

Table 3. Johansen trace test

	Trace	Pr. (0.1)	Pr. (0.05)	Pr. (0.01)
Panel A: One-Minute Returns				
$r <= 3$	5.9190	10.4900	12.2500	16.2600
$r <= 2$	28.9316	22.7600	25.3200	30.4500
$r <= 1$	87.4962	39.0600	42.4400	48.4500
$r = 0$	241.9822	59.1400	62.9900	70.0500
Panel B: Five-Minute Returns				
$r <= 3$	6.7007	10.4900	12.2500	16.2600
$r <= 2$	24.4847	22.7600	25.3200	30.4500
$r <= 1$	61.0764	39.0600	42.4400	48.4500
$r = 0$	143.1154	59.1400	62.9900	70.0500

Notes: The standard Johansen (1991) trace test to determine the number of common long-run trends for the four series: CSI 300 spots, CSI 300 futures, A50 spots and A50 futures. r is the number of cointegrating vectors, Trace is the trace test statistics, Pr. (α) is the trace test critical values for probability α with the null hypothesis that the number of cointegrating vectors is less than or equal to r, with α being to 0.1, 0.05 and 0.01, respectively. Panel A is for one-minute returns and panel B is for five-minute.

Table 4. Pairwise Granger causality test

	Joint test	p-value	Speed of adjustment	p-value
Panel A: One-Minute Returns				
The CSI 300 future market did not Granger-cause the CSI 300 spot market	969.5890	0.0000	-6.9837E-03	0.0000
The CSI 300 spot market did not Granger-cause the CSI 300 futures market	2.4201	0.0016	-4.3591E-03	0.0296
The A50 futures market did not Granger-cause the A50 spot market	85.4647	0.0000	-2.8207E-03	0.0056
The A50 spot market did not Granger-cause the A50 futures market	44.2777	0.0000	-2.3296E-03	0.0757
The CSI 300 futures market did not Granger-cause the A50 futures market	158.8433	0.0000	3.8362E-04	0.1691
The A50 futures market did not Granger-cause the CSI 300 futures market	1.3226	0.1783	-7.5102E-04	0.0097
The CSI 300 spot market did not Granger-cause the A50 spot market	8.8562	0.0000	4.1736E-04	0.0790
The A50 spot market did not Granger-cause the CSI 300 spot market	989.7955	0.0000	-3.3328E-04	0.0348
Panel B: Five-Minute Returns				
The CSI 300 future market did not Granger-cause the CSI 300 spot market	88.4284	0.0000	-2.0334E-02	0.0369
The CSI 300 spot market did not Granger-cause the CSI 300 futures market	1.8333	0.0574	-2.1263E-02	0.0459
The A50 futures market did not Granger-cause the A50 spot market	15.2561	0.0000	-7.1474E-03	0.2690
The A50 spot market did not Granger-cause the A50 futures market	0.6908	0.7180	-7.7389E-03	0.2572
The CSI 300 futures market did not Granger-cause the A50 futures market	7.1818	0.0000	2.6294E-03	0.0746
The A50 futures market did not Granger-cause the CSI 300 futures market	0.8169	0.6005	-3.6643E-03	0.0153
The CSI 300 spot market did not Granger-cause the A50 spot market	4.3790	0.0000	2.8699E-03	0.0522
The A50 spot market did not Granger-cause the CSI 300 spot market	46.8389	0.0000	-3.5265E-03	0.0190

Notes: a pairwise block exogeneity test with lagged returns for markets i and j: $\Delta p_{i,t}=\alpha(p_{i,t-1}-p_{j,t-1})+\sum_{k=1}^{N}(\beta_{i,k}\Delta p_{i,t-k}+\beta_{j,k}\Delta p_{j,t-k})+\gamma D_t+\varepsilon_t$. Joint test is to determine whether market j Granger-causes market i (via a joint test that all coefficients $\beta_{j,k}$ are significantly different from zero); speed of adjustment is for whether market j is adjusting toward market i through a test of the statistical significance of α. Associated p-values are reported.

Table 5. Hasbrouck information shares

	CSI 300 Spot	CSI 300 Futures	A50 Spot	A50 Futures
Panel A: One-Minute Returns				
mean		73.5764%		26.4236%
upper bound		95.1952%		48.0424%
lower bound		51.9576%		4.8048%
mean	30.0657%	69.9343%		
upper bound	57.8157%	97.6843%		
lower bound	2.3157%	42.1843%		
mean			39.3504%	60.6496%
upper bound			77.1596%	98.4587%
lower bound			1.5413%	22.8404%
mean	57.9567%		42.0433%	
upper bound	97.9845%		82.0710%	
lower bound	17.9290%		2.0155%	
Panel B: Five-Minute Returns				
mean		63.1085%		36.8915%
upper bound		96.8129%		70.5958%
lower bound		29.4042%		3.1871%
mean	46.6270%	53.3730%		
upper bound	89.5518%	96.2979%		

lower bound	3.7021%	10.4482%		
mean			44.3531%	55.6469%
upper bound			88.3184%	99.6121%
lower bound			0.3879%	11.6816%
mean	60.6821%		39.3179%	
upper bound	95.2111%		73.8468%	
lower bound	26.1532%		4.7889%	

Notes: This table reports the Hasbrouck information share value, which measures the contribution of a particular market to the total variation in common trend innovations that drive two markets. Besides standard upper and lower bound, mean value is computed as the average of them. A larger value indicates that market contributes more than the other market in price discovery process.

Table 6. Gonzalo-Granger information shares

	CSI 300 Spot	CSI 300 Futures	A50 Spot	A50 Futures
Panel A: One -Minute Returns				
		76.7079%		23.2921%
	23.9323%	76.0677%		
			23.7676%	76.2324%
	77.3104%		22.6896%	
Panel B: Five-Minute Returns				
		75.4335%		24.5665%
	38.5172%	61.4828%		
			16.3926%	83.6074%
	69.4183%		30.5817%	

Notes: This table presents the Gonzalo-Granger information share value, a measure that focuses on the contribution of each market has in influencing an implicit efficient price that is common to two markets. A larger value suggests that market leads the other market.

Table 7. Volatility transmissions

Panel A: 1-*min returns:*

Matrix A	CSI300 spot	CSI300 futures	A50 spot	A50 futures
Estimate		0.9784		0.0000
t-stat		29.6481		0.0003
Estimate	0.9862	-0.0016		
t-stat	46.1545	-0.3243		
Estimate			2.2073	0.1385
t-stat			8.9635	2.3014
Estimate	1.9767		-0.2965	
t-stat	3.9010		-127.9844	

Matrix B	CSI300 spot	CSI300 futures	A50 spot	A50 futures
Estimate		-0.2548		0.0784
t-stat		-91.0310		17.1369
Estimate	-0.0126	0.1875		
t-stat	-0.6424	44.7307		
Estimate			-0.5021	0.1236
t-stat			-13.8487	37.4546

Estimate	-50.4114		0.0043	
t-stat	-47.9542		70.0007	

Panel B: 5-min returns:

Matrix A	CSI300 spot	CSI300 futures	A50 spot	A50 futures
Estimate		0.9749		0.2272
t-stat		3.0279		4.6590
Estimate	4.5862	-2.4966		
t-stat	25.4318	-42.1766		
Estimate			0.9605	0.0448
t-stat			13.2403	1.1003
Estimate	0.9942		-0.1247	
t-stat	0.6239		-13.4946	

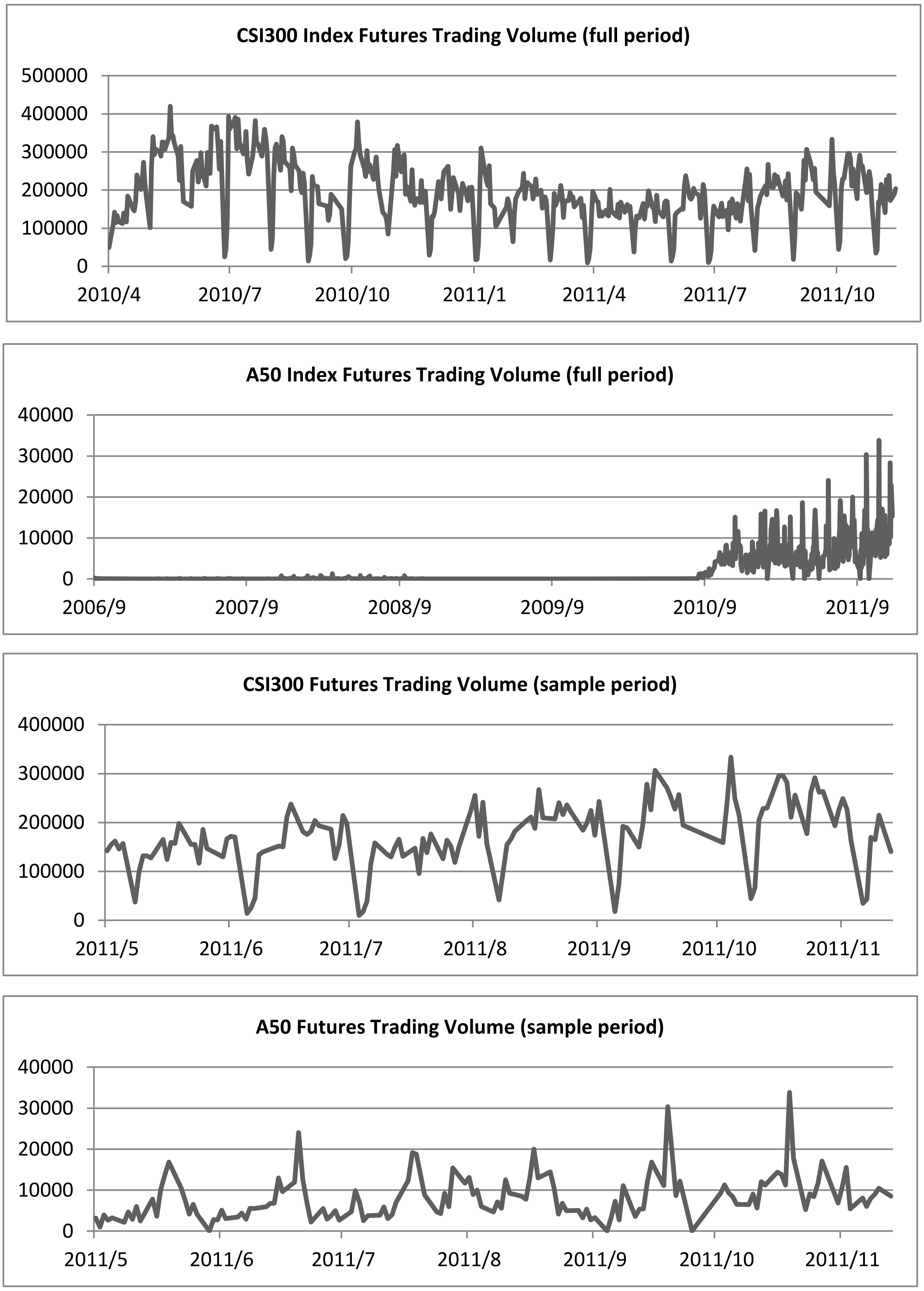
Matrix B	CSI300 spot	CSI300 futures	A50 spot	A50 futures
Estimate		-3.9873		-0.0148
t-stat		-134.4148		-5.9863
Estimate	-0.6378	-0.0143		
t-stat	-33.8072	-4.7498		
Estimate			0.9814	0.0841
t-stat			24.6365	9.5352
Estimate	0.8770		0.0101	
t-stat	1.4543		117.6082	

Notes: This table shows the results for volatility transmission analysis using an ECM-GARCH(1,1) model with BEKK specification, with the covariance matrix defined as in equation (4):

$$H_t=\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix}=\begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}\begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}^{\mathrm{T}}+\begin{bmatrix} a_{11} & a_{12} \\ 0 & a_{22} \end{bmatrix}^{\mathrm{T}}\varepsilon_{t-1}\varepsilon_{t-1}{}^{T}\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}+\begin{bmatrix} b_{11} & b_{12} \\ 0 & b_{22} \end{bmatrix}^{\mathrm{T}}H_{t-1}\begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}.$$

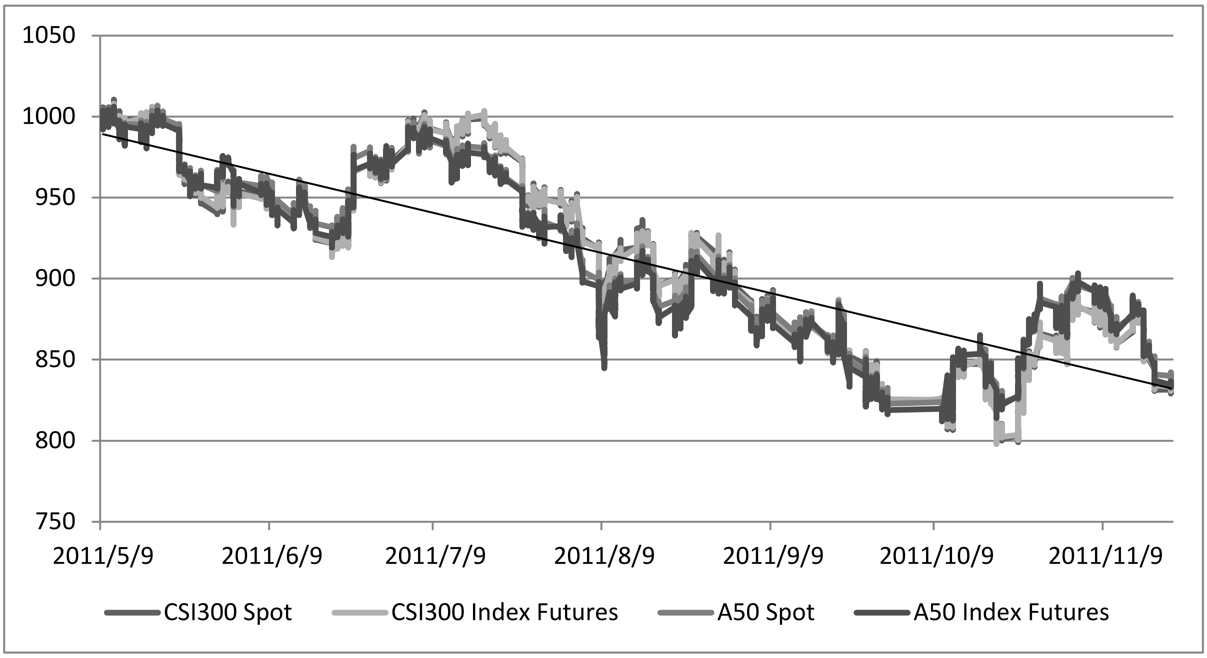
The off-diagonal parameters in matrices *A* and *B* explaining volatility transmission effect are listed in the table.

Figure 1: Trading volume: CSI 300 futures vs. A50 futures



Notes: The above two figures are time series plots of the daily trading volume from the first day of trading to November 21, 2011 (full period). As a comparison, the bottom two figures are only for the sample period used in this study.

Figure 2. Time series plot of four markets



Notes: time series plot of the four markets from May 2011 to November 2011 used in this study. All indices are normalized by setting the first-day price/the index value in each series to be 1,000.